O219-P007 **Room: Poster Session Hall** **Time: May 27**

An application of seismic azimuthal anisotropy using a land 3D seismic data.

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We analyzed azimuthal (horizontal) anisotropy of seismic transmission velocity using 3D land seismic data in a Middle East oil field, for understanding subsurface anisotropy such as anisotropic horizontal stress or possible fractures. By applying sufficient compensation, we extracted trustworthy distribution of azimuthal velocity variation from the 3D seismic data acquired with rectangular acquisition geometry that was not perfectly suitable for the azimuthal seismic analysis.

The 3D data was acquired with so called 'orthogonal' geometry, in which geophones along eight receiver lines collected reflected waves induced by a seismic source placed in the middle of the receiver 'patch.' The inline maximum offsets was 3.6km and the crossline maximum offset varied from 1.8km to 2.2km periodically, making the geometry rectangular and asymmetric with respect to rotation. The nominal fold number was 36 for 25 x 25 meter bin.

For using sufficient volume of data for individual azimuthal angles, we first generated super-gather data for 400m x 400m super-bins. The super gathering also reduced footprints due to laterally periodical crossline offset variations. Synthetic data analysis demonstrated that the applied super-gathering dramatically stabilized amplitude data quality. For minimizing the influence of structural dip on the super-binning that presupposes flat reflectors, we applied reflection traveltime correction similar to Dip Move Out, which did not harm the seismic anisotropy information in the data.

After these pre-processing, we applied extracted azimuth dependence of seismic velocity at individual superbins. This analysis delivered vector output at each location, 1) intensity of velocity anisotropy (The ratio of fastest and slowest velocities) and 2) orientation of fast velocity. These outputs were visualized by vectors at each super-bin, whose directions and lengths corresponded to the orientation and strength of velocity anisotropy.

In the estimated velocity anisotropy result, the fast velocity orientation was predominantly along NE-SW, which turned out to be consistent with the in-situ maximum horizontal stress orientation interpreted from borehole breakout orientation in the resistivity image log data. Besides, the magnitude of seismic velocity anisotropy increased towards NE, i.e., to the proximity of active mountain range, and may indicate lateral variation of in-situ stress magnitude. However, we also identified an inherent problem of this technique; shallow velocity heterogeneity, such as channels, can induce apparent azimuthal traveltime variation, and detailed interpretation of shallow sections was necessary for avoiding mis-interpretation.

By applying sufficient pre-processing, we extracted reliable subsurface anisotropy information from a land 3D seismic data that was not perfectly designed for the azimuthal seismic analysis. The extracted anisotropy data was consistent with other sources and was interpreted to represent in-situ stress information.